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Bulletin

Tennessee. Division of Geology



STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST
SUCCEEDED BY
A. H. PURDUE

IN CO-OPERATION WITH THE
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
HENRY S. GRAVES, FORESTER

BULLETIN 10-C

**YELLOW POPLAR IN
TENNESSEE**

BY
W. W. ASHE
FOREST EXAMINER, U. S. FOREST SERVICE



NASHVILLE, TENNESSEE
1913

WILLIAMS PRINTING COMPANY, NASHVILLE

STATE GEOLOGICAL COMMISSION.

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PREFATORY STATEMENT

The study upon which this report is based was undertaken by the State Geological Survey in coöperation with the Forest Service, the work being done under the office of State Coöperation in the Forest Service, and under the local instruction of the State Geologist of Tennessee. By the terms of the coöperative agreement the state is authorized to publish the findings of the investigation. At the time arrangements for the work were made, George H. Ashley was State Geologist, but he subsequently resigned and was succeeded by A. H. Purdue.

YELLOW POPLAR IN TENNESSEE.

By W. W. ASHE.

CORRECTIONS

- Page 5. Line 4 from top read: "69,612,000" in place of "69,612."
Line 5 from top read: "1,567,000,000" in place of "1,567,000."
- Page 16. Line 2 from bottom read: ".23 per cent." in place of "23 per cent."
- Page 17. Line 6 from bottom read: "different" in place of "difficult."
- Page 29. Line 13 from top read: "The values" in place of "The value."
- Page 30. Following heading of the table read: "*Estimated.*"
- Page 32. Line 18 from top read: "The advantages" in place of "The advantage."
- Page 36. Line 14 from top read: "5 per cent. a year" in place of "5 per cent."
- Page 54. In footnote insert: "Table 20."
- Page 55. Lines 25 and 26 read: "thinned stands" (page 17) in place of "thinning stands."

(NOW is the best time to make the corrections.)

... lumber companies that were interviewed in Tennessee report from 15 to 20 years supply of yellow poplar timber. On the basis of 20 years' supply the total stand of old yellow poplar timber in Tennessee is about 2,500,000,000 board feet.

The highest production of yellow poplar lumber in Tennessee was doubtless obtained between 1907 and 1910. Since 1910 the output from Tennessee has declined from 138,000,000 board feet to 107,000,000 board

*Botanically, yellow poplar is known as *Liriodendron tulipifera* L. The tree is also known as tulip tree and whitewood.



YELLOW POPLAR IN TENNESSEE.

By W. W. ASHE.

COMMERCIAL OUTLOOK.

On the basis of the present cut of lumber, yellow poplar* ranks as the second tree in importance in Tennessee. In 1912 there were 378,747,000 board feet of oak sawed in Tennessee; 107,265,000 board feet of yellow poplar; and 69,612 board feet of red or sweet gum. The total cut of lumber in the state was 1,567,000 board feet. The total cut of yellow poplar in the United States was 623,287,000 board feet. The value of the cut of 1912 is not yet available from the census returns. Oak leads, with a cut during the year 1911 of 382,000,000 feet board measure, valued at \$7,790,000, followed by yellow poplar with a cut of 119,000,000 feet board measure, valued at \$3,360,000. Chestnut and red gum each had about one-half the cut of yellow poplar, but the output of each was only about one-third as valuable. The average value of oak lumber in 1911 at the mills in Tennessee was \$20.68 per 1,000 feet board measure; poplar \$28.22; red gum \$12.33, and chestnut \$16.91.

In 1906 the cut of yellow poplar in Tennessee was 110,480,000 board feet, the state contributing 19 per cent. of the total cut of yellow poplar in the United States.

In 1907 the cut was 137,900,000 feet board measure, being 16 per cent. of the total cut of the United States, the average price of yellow poplar lumber in Tennessee being \$24 per 1,000 board feet.

In 1910 the cut was 138,705,000 board feet, 19 per cent. of the total cut of this species in the United States, the average price of its lumber in Tennessee being \$28.10 per 1,000 board feet.

In 1911 it was 119,000,000 board feet, about 19 per cent. of the total cut of the United States. In 1912 the cut declined to 107,265,000 board feet, 17 per cent. of the total cut of the United States.

Many lumber companies that were interviewed in Tennessee report from 15 to 20 years supply of yellow poplar timber. On the basis of 20 years' supply the total stand of old yellow poplar timber in Tennessee is about 2,500,000,000 board feet.

The highest production of yellow poplar lumber in Tennessee was doubtless obtained between 1907 and 1910. Since 1910 the output from Tennessee has declined from 138,000,000 board feet to 107,000,000 board

*Botanically, yellow poplar is known as *Liriodendron tulipifera* L. The tree is also known as tulip tree and whitewood.

feet. While this decline in cut will continue for some time it is possible, by protecting and managing the young growth, to have it replace the old timber, and in this manner to maintain a continuous, though undoubtedly reduced, output of this valuable lumber.

The greater and more valuable portion of the cut of yellow poplar is the product of old timber. In order that the lumber may average \$28 per 1,000 board feet, the trees from which this lumber is sawed must have, at present prices of lumber, an average diameter of 27 inches, breast-high. Although the amount of young timber which is cut for commercial purposes is small, it has a standard and rapidly increasing value for saw timber. With the continued reduction in the supply of old timber, the second growth must become the chief source of future supply. And consequently it is extremely important to know something of the amount of young growth and its probable future price. It is also desirable to know the rate of growth of the young timber, the possible profit in growing it, and the best methods of management for accelerating its growth and increasing its value.

The results of an investigation in Tennessee show that yellow poplar has a comparatively rapid rate of growth while young; it seeds abundantly and reproduces freely on suitable sites, forming either pure groups or a considerable proportion of mixed seedling stands. On account of its soft, white wood, which is very free from large knots, it is merchantable even when of small diameter, while on account of its straight stem with only moderate taper it yields under the saw as large a proportion of lumber per cubic feet of total volume as do the pines. On account of its intolerance of shade its yield per acre is less than that of chestnut and some of the pines, but this is offset by the rapid growth of the individual tree and its vigorous response to thinnings. On the whole, no other species of tree which has a wide distribution in Tennessee offers such excellent inducements for the protection of small trees, and even for propagation and planting. Not only is there an assured and remunerative market for the timber of small sized trees but its rate of growth is so rapid that returns are obtained at an early period for a forest tree. Second growth trees are largely "sapwood" or "white poplar," but there is now no discrimination against lumber from this grade of timber, and the clear sap lumber at present commands a higher price than the best yellow heartwood did 20 years ago.

Yellow poplar is also extensively used in Tennessee for wood pulp for the manufacture of paper. While some wood from the limbs of large trees which are cut for saw timber goes into this product the greater portion of it comes from young trees of pole size the white wood of which renders such trees very desirable.

It is also extensively employed for veneers for baskets and crates and for excelsior.

DISTRIBUTION.

Yellow poplar is commercially important throughout Tennessee. It is most abundant on the limestone valley lands of the great basin and in the valley of East Tennessee; in the coves and hollows of the Cumberland Mountains; and in the lower coves of the Unaka and Smoky mountain ranges; but it nevertheless reaches a large size in such counties of West Tennessee as Obion, Dyer, and others which lie west of the barrens. Above 3,500 feet elevation in the Unaka and Smoky mountains it occurs only irregularly. It is very largely absent from the thin soiled summit of the Cumberland Mountains, from the drier portions of the shale and sandstone ridges and from the barrens. Even when most abundant it seldom forms numerically as much as 10 per cent. of the forest over more than a few acres, but on account of the large size of the trees it frequently contributes from 20 to 25 per cent. of the merchantable timber in the bottoms and on the lower slopes, and may form 50 per cent. of the value of stand. The yield of poplar lumber seldom amounts to as much as 500 board feet per acre over a large tract, and frequently is less than 200 feet per acre.

The following table shows the number of trees of different diameters per acre in Tennessee on a large tract which has been examined by the Forest Service. If this tract represents average conditions of the hardwood forest of Middle and Eastern Tennessee, there is sufficient young poplar in the stands to assure a large future cut of timber, provided the young trees are not cut before they reach the size of maturity for saw timber.

Number of trees of yellow poplar per acre on an unlogged tract.

Diameter Inches Breast-high	Scott and Anderson counties (Cumberland Mt.)
Under 12	4.
13-20	1.3
21-30	1.3
Over 30	.1

On cut-over and closely culled land which has not been badly burned, there is as a rule a large number of small poplar trees in the coves and hollows. These trees have sprung up in the openings which were made in logging. Occasionally they form a continuous stand in the narrow mountain valleys or form groups, pure or nearly pure, from a square rod to several rods in extent. There is often a far larger proportion of pop-

lar numerically in young stands on cut-over land than there was in the original forest. This young timber will constitute a very important element in the yellow poplar supply of the future. On the other hand on forest lands from which the old yellow poplars were removed before any of the other hard woods were cut, there is usually a poor replacement of young yellow poplar. There was not enough light for the establishment of yellow poplar, and seedlings of other species which are more tolerant of shade, occupied the space from which the yellow poplar was cut. Where tracts have been badly burned, the young yellow poplar has been largely killed.

In farmers' wood lots there is as a rule a large amount of young poplar except where the pasturage of cattle has suppressed the young trees, which is the case on many farms. There are, however, many pure stands of young yellow poplar of sapling and pole size, on farms which have sprung up in old pastures that were under fence so that cattle were excluded. While the total acreage of these stands is not large, they can be made where they occur, extremely valuable, if given proper management.

There is likewise a considerable acreage of second growth timber in old coalings. While these stands are largely formed of chestnut and oak sprouts, they generally contain, in the coves and hollows, a larger percentage of yellow poplar than the original forest.

While there is undoubtedly an excellent representation throughout Tennessee, of sapling and small pole-sized yellow poplar in second growth, there is a deficiency of large pole-sized trees which might become merchantable as large saw timber, during the next 20 to 25 years.

Notwithstanding the generally excellent representation of young growth yellow poplar, the future supply of this timber is threatened by the inroads which are being made on the young growth, by cutting it before it is mature, for paper-pulp stock and box-board bolts.

FOREST CHARACTERISTICS.

Form of stem and root system.—Mature poplar trees attain large sizes. It is one of the largest, if not the largest, species occurring in Tennessee. In diameter it may occasionally be surpassed by the sycamore, and in height by the cottonwood and hemlock (spruce pine), but none of these equals yellow poplar in both dimensions. Individual trees in Tennessee have been measured which had total heights of more than 140 feet, and diameters measured above the root swelling of more than 60 inches; while heights of more than 150 feet and diameters exceeding 75 inches have been recorded, but not in the same tree. The length of stem free of branches of mature trees varies from 50 to 75 feet. The crown generally occupies from 40 to 50 per cent. of the total height. The stem is column-

lar, tapering very slightly, and is very free from crooks and forks. About the middle of the crown, the stem divides into branches and its identity is lost. The lower branches die off rapidly until the full length of the stem is formed, and the scars which are left by them heal quickly and smoothly. This is one of the most valuable characteristics of the tree. Water sprouts occasionally appear on the trunks of trees exposed to sunlight, but the stems are never injured by the growth of such sprouts, as is the case with white oak.

While the stem of the old trees usually forks within the crown, young trees, particularly those in even-aged crowded stands, as a rule have



FIG. 1. Trees of yellow poplar which have been isolated in a second-growth stand by the removal of the chestnut and red oak. As a result of the isolation these trees are in condition to make rapid diameter growth. Since there is no undergrowth the restocking should be largely formed of poplar. (Photo Forest Service.)

straight undivided stems to the very top of the crown. Since the branches on them are small, logs which lie within the crowns of young trees are suitable on account of their straightness both for sawlogs and for pulpwood. This character which permits the close utilization of young trees, adds to their value.

The seedling yellow poplar has a long, straight taproot, which bears only a few fleshy rootlets. The taproot interferes with transplanting. Seedlings when transplanted do not readily establish themselves on account of the few rootlets.

Old trees have a very deep-seated and strong root system which renders them windfirm.

SILVICAL CHARACTERISTICS.

Soil and moisture requirements.—Yellow poplar requires for its best growth a deep, fertile and moist, but well drained, soil. It has a strong preference for soils which are derived from limestone, although it is common on other fertile soils which are rich in humus. It makes very slow growth and reaches only a small size, however, on either wet or extremely dry soils. The most congenial sites for it are the lower slopes and hollows of the mountains, and the soils of the rolling limestone valleys which are well drained through the underlying fissured rock. The soils occupied by yellow poplar are usually of high agricultural value for the growing of grain and grass, and, consequently when not too steep have been largely cleared and placed in cultivation. The chief remaining areas of considerable size which contain merchantable yellow poplar and which are best suited for its growth are the hollows along the Cumberland Mountain, the lower slopes and coves of the Smoky and Unaka range, and the hollows of the intervening ridges. The small tracts of forest which yet remain on the farms of the limestone valleys frequently contain considerable old poplar, and on many tracts a large amount of young timber, and are well suited for its growth.

Temperature and light.—In spite of its exacting requirements respecting soil moisture, yellow poplar demands considerable warmth. It grows well from the lowest elevations in Tennessee up to altitudes of 3,000 feet on the north slopes of the Unaka and Smoky mountains, but it becomes sporadic on north aspects above this altitude. It demands a large amount of direct sunlight for its best growth, at all ages after it is thoroughly established.

The seedling and young tree will endure considerable side shade, more on moist than on dry soils, but if the overhead shade is too dense or is prolonged, the tree dies. A very light overhead shade or a side shade is beneficial to seedlings until they are two years old, by which time they

should be well established. On account of its intolerance of shade the stem clears itself of branches thoroughly when the trees are crowded.

Reproduction.—Yellow poplar reproduces chiefly by means of seed. It reproduces to a limited extent by means of sprouts but only from small trees until they reach the size of poles; the sprouting of old trees is unreliable. Sprouting is best in full sunlight. The sprouts from trees which are shaded are weak. The seeds, which are borne in small cones, are about one inch long, including the slender wing, and are so light that they may be blown several hundred yards from the parent tree. The seeds from the top of the cone and from the exterior will not germinate. These are the last to fall from the tree, often remaining until the following spring, and in collecting seed for planting they should be discarded. Trees begin to bear fertile seed when about 40 years old. Seeds are produced on older trees in great abundance and almost annually, but a large proportion, as a rule about 90 per cent., are infertile. They ripen in September and October and are in great part distributed at once by the wind. They largely germinate during the following spring and the early part of the summer, but some seem to lie over on the ground until the second spring. Germination takes place wherever the soil is moist, and the seedlings easily establish themselves, but they fail to survive the dry periods of the first summer unless on a moist or shady site. Stocking, consequently, is better on north slopes, in coves and hollows or in lower slopes, than on the drier upper slopes and on southern exposures. It is also best where the mineral soil has been exposed, as in old fields or where the soil has been upturned by logging or by hogs. A thick layer of dry leaves is unfavorable.

Diseases and defects.—While old trees of yellow poplar have many defects, such as wind-shake, frost crack, and stained wood, there are, so far as known, no destructive fungous diseases or insects which attack and kill trees.

Sensitiveness to fire.—Seedlings and small trees of yellow poplar are extremely sensitive to fire, being more easily injured even than chestnut. This is due primarily to the thin and smooth bark of the young tree of yellow poplar. An additional reason for their great injury is that the sap and inner bark of yellow poplar become active earlier than in the associated trees. This greatly exposes this species to early spring fires, which, when they take place during dry and windy periods before the forest foliage is out, are very hot and destructive. Fortunately yellow poplar is somewhat protected by being largely confined to the damp hollows and coves. Seedlings of yellow poplar which are killed down by fire will usually sprout from the root, unless they are shaded. This power, however,

is feeble when compared with that of many other broad-leaf species with which it is associated, particularly with that of chestnut, because after a small poplar has been killed down by fire a few times, the root generally dies. Old trees of yellow poplar are protected by their thick bark, and are rarely killed outright. However, many old trees on dry sites have butt hollows, which open on their upper side and which resulted from fire.



FIG 2. A group of yellow poplars which are growing on a rocky slope and which have been injured at the butts by fire. Note the hollow on the left of the base of the large tree and the scar to the right of the hollow, both caused by fire.

Other injurious agencies.—The tender shoots and leaves of small yellow poplars are freely eaten by cattle and sheep. For this reason stock should not be grazed on areas which are in process of stocking until the small trees become 8 to 10 feet in height. Hogs do not eat yellow poplar roots. They dig up seedlings, however, while rooting for other food on

fertile slopes and coves. The leader of yellow poplar is rarely broken by sleet. Both old and young trees are very windfirm.

Properties and uses of the wood.—The wood of yellow poplar is soft, light, stiff, and rather brittle, but close-grained. The heartwood varies in color from nearly white to a yellowish brown; the sapwood is white. The heartwood shows only a slight tendency to warp and shrink, and is durable when exposed to the weather, but only moderately so in contact with the soil. The sapwood is much less durable than the heartwood when exposed; and shrinks, warps and checks more, but if carefully kiln-dried the tendency to these defects is reduced. Air-dried, the wood has a specific gravity of .42 and weighs from 26 to 28 pounds* per cubic foot. Rough, kiln-dried lumber weighs about 2,800 pounds to the 1,000 board feet, but the green wood is much heavier. While slightly heavier than white pine, poplar has about the same relative strength (Modulus of elasticity 1,716,000; modulus of rupture, 10,850)†, and is consequently adapted to nearly the same uses. It withstands end-compression well, has high shearing strength and abrades quite even and slowly. While it does not split easily, the fracture is straight and clean.

In the center of thrifty second-growth trees there are frequently as few as three rings of annual growth to an inch of radius; while the periphery of young trees, stimulated to growth by isolation, may be equally as coarse-grained. In old trees, twelve rings per inch of radius is usual, and commercial timber will generally show from ten to fifteen rings per inch. There is a little difference in density between the early and late wood in the annual band. The numerous pores are small and uniformly distributed through both early and late wood of the annual band. The pith rays or medullary rays are of uniform size, nearly invisible to the naked eye, and scarcely raised when the wood is split radially. While the grain of the wood is as a rule extremely straight, it is occasionally wavy or curly, a characteristic which is usually limited to one face or one side of a tree. Occasionally trees are burly or bird's eyed.

The proportion of heartwood varies with age, and is much greater in old trees. It begins to form at from fifteen to thirty-five years of age, earlier on good than on poor sites. Its formation, however, does not continue regularly and at the same rate as the growth of the tree, but more slowly, since a tree seventy-five years old will usually have more than forty rings of sapwood. Young trees on average soils which are fifty years old or less, are for this reason largely sapwood and have only a small core of heartwood. In young trees this large proportion of sap-

*Sargent, Tenth Census.

†Tests by Branch of Products, U. S. Forest Service.

wood has retarded their use for lumber to a considerable extent. Young, thrifty sap trees are called "hickory poplar," on account of the toughness of their wood.

Soil and moisture conditions cause a considerable variation in the amount and color of heartwood and the percentage of moisture in the wood. Trees growing on uniformly moist but well-drained soils (well aerated), such as fertile coves and best limestone soils have a thin sapwood, heartwood, dark brownish-yellow or canary yellow in color, containing a low percentage of moisture and the lumber from such trees consequently is not so subject to shrinking, checking, or warping. Large old trees on such sites, as a rule, have less than one inch of radial sapwood. Second growth trees on similar sites, 12 inches in diameter and sixty years old, often have less than 1.5 inches of sapwood on the radius. On the other hand, on dry soils, the trees have a small, pale yellow or nearly white heartwood ("white" or blue poplar") and a very thick sapwood. Such dry soils may be either physically dry as in the case of coarse sands, fissured slates or very fine grained clay, when the water table is low or fluctuates, or physiologically dry, as in the case of such sour soils as are poorly drained, because of deficient aeration. On "dry" sites the sapwood which acts as a water reservoir is sometimes so thick as to include one-half the radius of a tree two feet in diameter. The wood of "white poplar" and "blue poplar" has a high percentage of moisture and is subject to shrinking, checking, and warping, but is tougher than that which is deep yellow. Trees with pale-colored heartwood are most subject to windshake and discolored (calico) wood. The canary yellow wood is most prized for general uses.

The lumber can be easily and quickly kiln-dried. The best results in commercial kiln drying are obtained by first subjecting the wood to live steam or to hot moist air which is subsequently replaced by a free circulation of warm dryer air; but the wood is not refractory when a dry chamber system is employed, and is not prone to case harden and check. Sapwood blues if piled closely. This can be prevented by immersing the timber in a 10 per cent. solution of bicarbonate of soda. Air drying, though slow, is effective. The wood is easily impregnated with preservatives, either with copper sulphate by the gravity process or with creosote or zinc chloride.*

The wood has other qualities which give it a very wide range of usefulness. It works easily and smoothly when dried, that from any one tree being comparatively uniform in quality and as a rule that from trees in one locality is very uniform in character. It absorbs stain easily, but on

*Branch of Products, U. S. Forest Service.

account of its dull uniform texture it seldom shows a handsomely grained surface. It is too soft to retain a high polish on untreated wood, but it takes paint well and if the paint is highly glossed, it holds the gloss indefinitely. The knots, which are small and infrequent, even in the case of small trees, except in lumber cut from the crown, are usually light colored and tight, plane smoothly and also take and hold paint well. For doors, paneling, vehicle bodies, especially for automobiles and office and church furniture, the wood is especially desirable. It holds glue strongly, and is desirable as a backing for costly veneers. The heartwood of trees with the deep yellow-colored wood, while not as durable in contact with the soil as that of many conifers, has been extensively employed for water pipes, wooden pumps, and outside steps. Such wood is durable on exposure to the weather—as for weather boarding, shingles, fencing, dug-out boats, and troughs—and was largely employed in Tennessee for these uses until its scarcity and high price required the substitution of cheaper woods. On the other hand, the sapwood of yellow-hearted trees and the entire wood of the “white poplar” are not durable if subject to the weather. Other uses of the wood are for the manufacture of packing boxes, printers’ materials, especially type cases, drawers, domestic and culinary woodenware. Among such articles which are made in Tennessee are dough bowls for bakers, which are turned in sizes up to four feet in diameter from one piece of wood. It is extensively employed in the manufacture of toys, cheap furniture, and interior woodwork. It is used in the form of veneer for baskets and crates. For the grape trade, which demands a white wood basket, the sapwood is used or the heartwood is bleached with sulphur.

A large amount of rotary-cut veneer is also produced in Tennessee for use in the manufacture of furniture, for built up stock, for packing boxes and trunks. Small and low grade logs are made into excelsior, wood fiber and ground wood; while slabs, veneer cores, small trees and limb wood of large trees are also used for paper pulp,* being reduced by the soda process and forming a close-felting and easily bleached fiber. Extra wide boards, twelve to thirty inches, cut in thin stock and cleated or bound in bundles, are largely exported from Tennessee to Europe and South America, where they are used for paneling and for vehicle bodies, but the timber is also exported in the squared log. The quarter-sawed lumber, which is manufactured in considerable amount, especially in wide widths, does not warp and is consequently more desirable than flat sawed lumber as a backing for veneers, for wide paneling and for vehicle bodies.

*The Columbia Paper Company, of Bristol, is the largest user of poplar pulp-wood in Tennessee.

The wood also enters largely into the construction of piano cases and other musical instruments. On account of lack of odor it is a desirable wood for cases for dairy goods, such as cheese boxes and butter tubs, and for cracker boxes and candy pails. It is extensively used in the manufacture of cigar boxes, either as a core for Spanish cedar veneer, or simply stained and printed in imitation of it. It is employed for bobbins and yarn spools, and in the manufacture of refrigerators, boats, and car finish. While the heartwood of old trees is preferred for most of these uses, the sapwood is being less discriminated against when well kiln-dried, and eventually must be largely used instead of the heartwood. To a great extent cheaper woods, like gum and tupelo, are replacing it for headings, for slack cooperage stock, for pumps, for cheap packing cases and for tobacco hogsheads. But it is still a standard wood for small packing boxes of the lock-end type, such as are largely used for drugs, as it shows for this use a greater strength for its weight than any other competing wood.* The white sapwood which admits of direct printing is preferable for this use. It is being substituted for white pine in making staves for fish kits and pails, patterns for castings, drawing boards and engineer's tables, and for pontoon bridge timbers, uses which demand clear boards. On the other hand it has been in part replaced by cheaper materials, such as gum and cottonwood in agricultural implements; by cottonwood and sap pine for wagon bodies, and by pine for exterior construction work.

On account of its great shearing strength, its capacity for withstanding end compression and the straightness of its stem, yellow poplar poles are well suited for mine props. In temporary workings (robbings) second growth sap timber can be used untreated, but where durability is essential the timber should be impregnated with a preservative. Treated wood is also adaptable for use as poles and fence posts. This adds greatly to the usefulness of the second-growth timber. It is well adapted for match sticks on account of the straightness of its grain, the ease with which the wood ignites, its free burning resulting in a steady flame, and the completeness of combustion. It has been used for this purpose, however, only to a limited extent.

The wood burns well and quietly, the embers glowing for a long while in still air. The fuel value of the wood compared with that of hickory, is low. The amount of ash is small, 23 per cent.† It makes a light charcoal which is held in low esteem.

*Tests of the woods used in the box trade made by Branch of Products, U. S. Forest Service, show that for its weight yellow poplar has the highest shearing and cross breaking strength. Cottonwood ranks next to it

†Sargent, Tenth Census.

GROWTH

The possibility of profitable management of yellow poplar largely depends upon the rate of growth of the young trees, both as individual trees in mixed stands and when in pure groups or pure stands. Table 1 gives the rate of growth of young trees in mixed stands, and of the dominant trees in irregularly thinned stands in height, diameter, volume in board feet, circular sawed $\frac{1}{4}$ -inch kerf, cubic feet of wood only without bark, and cords of 160 cubic feet of peeled wood, measured after it is stacked and dry. The peeled cordwood is measured as required for paper-pulp stock.

TABLE 1.—*Rate of growth of young trees of yellow poplar.*

Age of trees	Scattered trees in the mixed forest					Dominant trees in pure, even-aged, thinned groups	
	Height	Diameter breast-high	Volume saw cut $\frac{1}{4}$ in. kerf	Volume wood without bark		Diameter breast-high	Volume saw cut $\frac{1}{4}$ in. kerf
	Feet	Inches	Bd. ft.	Cubic ft.	Cords of 160 ft.	Inches	Bd. ft.
Years 20.....	40	4.6	...	2.2	.02	5.7	
30.....	61	7.7	44	7.6	.07	8.5	54
40.....	78	10.5	111	22.	.19	11.1	121
50.....	87	12.8	177	29.2	.20	13.7	200
60.....	94	14.7	241	42.1	.38	16.1	286

The rate of growth of single young trees in the mixed hardwood forest is slower than that of the larger or dominant trees in pure even-aged groups which occur in cut-over land and in old fields. This is largely due to the fuller light conditions under which the pure even-aged groups grow. The narrow crowned intermediate trees in the pure stands, whose tops do not enjoy full sunlight, have nearly the same rate of growth as the scattered trees in the mixed, many-aged forest. It is believed that by systematically thinning young stands, an average diameter of 20 inches, breast high, can be obtained for all trees in a stand when 60 years old.

The figures in Table 1 are an average of the growth under many difficult conditions of soil and moisture. On the less favorable sites, such as upper slopes and on wet bottoms, the rate of growth is slower than that of the average; on the more favorable sites, such as the better coves and limestone valleys, the rate of growth is more rapid. Individual trees in particular will be found, which depart widely from the average—espe-

cially larger trees among the dominant class in the even-aged stands, the growth of which is far more rapid, and the small trees in the suppressed class, the growth of which is much slower.



FIG. 3. Section of stem of yellow poplar 12 inches in diameter, illustrating accelerated growth following isolation. The growth in diameter during the last eight years amounted to 7 inches compared with the previous growth of 5 inches during 30 years while the stand was crowded.

Table 2 shows the volume in board feet $\frac{1}{4}$ -inch saw kerf of trees of different heights and diameters.

TABLE 2.—*Volume in board feet of second growth trees of yellow poplar.
Mill cut, $\frac{1}{4}$ -inch saw kerf.*

Diameter breast- high Inches	Number of 16-foot logs per tree							Diameter inside bark of top Inches
	1	1½	2	2½	3	3½	4	
	Volume — Board feet							
7	19	38	54	..	..	..	..	6
8	20	41	59	78	..	..	..	6
9	23	44	64	85	..	..	..	6
10	25	48	70	90	120	..	..	6
11	27	52	77	99	130	150	..	7
12	29	57	83	110	140	170	210	7
13	32	61	90	120	150	190	230	7
14	33	68	99	140	170	210	250	7
15	35	72	110	140	180	230	270	7
16	37	78	120	150	200	240	290	7
17	39	85	130	170	220	260	320	7
18	41	90	140	180	230	290	340	8
19	..	110	150	200	250	310	360	8
20	..	..	170	220	270	320	390	8
21	..	..	..	230	290	350	410	8
22	..	..	..	250	320	380	440	8
23	..	..	..	..	330	410	470	8
24	..	..	..	..	350	420	500	8
25	..	..	..	..	..	440	520	8
26	..	..	..	..	..	470	550	8

TABLE 3.—*Volume of trees of yellow poplar of different diameters and heights as scaled by the Doyle-Scribner rule. Age class, 50 to 100.*

Diameter breast- high Inches	Height of tree — Feet							Diameter inside bark of top Inches
	70	80	90	100	110	120	130	
	Volume — Board feet in tens							
9	1	1	1	..	..	..	..	6
10	2	2	3	3	..	..	..	6
11	3	4	4	5	..	..	..	7
12	4	5	6	7	..	..	..	7
13	6	7	8	10	..	..	..	8
14	8	9	11	12	14	15	..	8
15	10	11	13	15	17	19	..	8
16	..	13	16	19	21	24	..	8
17	..	15	19	23	26	29	..	9
18	..	18	23	27	31	34	37	9
19	..	20	26	31	36	40	43	9
20	..	23	30	36	42	46	50	10
21	..	..	34	41	48	53	57	10
22	..	..	39	47	54	60	64	10
23	..	..	44	53	60	67	72	11
24	..	..	50	58	66	74	80	11
25	..	..	..	63	74	82	87	12
26	..	..	..	69	80	89	95	12
27	..	..	..	75	88	98	103	12
28	..	..	..	..	96	106	112	13
29	..	..	..	..	104	115	120	13
30	..	..	..	..	113	124	129	14

This table was made from taper curves by scaling the merchantable length in log lengths to the top diameters shown. Logs were 16.3 ft. long whenever possible, with some 14.3-ft., 12.3-ft., and 10.3-ft. logs to avoid waste. The assumed stump height was 2 feet.

TABLE 4.—*Volume in board feet of old trees of yellow poplar scaled by Scribner Decimal C rule.*

Diameter breast- high Inches	Number of 16-foot logs												Diameter inside bark of top Inches
	1	1½	2	2½	3	3½	4	4½	5	5½	6		
	Volume — Board feet												
9'	19	33	47	62	..	..	..	..	..	..	..	6	
10	20	35	51	70	93	..	..	..	..	..	..	6	
11	22	39	58	82	110	..	..	..	..	..	..	7	
12	24	44	65	93	130	170	..	..	..	..	..	7	
13	27	49	74	110	140	190	..	..	..	..	..	8	
14	30	54	83	120	160	200	250	..	..	..	..	8	
15	33	60	93	130	180	230	280	..	..	..	..	8	
16	36	68	100	150	200	250	300	350	..	..	..	8	
17	39	76	120	160	220	270	330	390	..	..	..	9	
18	42	84	130	180	240	310	370	430	480	..	..	9	
19	..	93	150	200	260	330	400	470	530	..	..	9	
20	..	..	160	220	290	370	440	520	590	660	..	10	
21	..	..	..	230	320	400	480	560	650	730	..	10	
22	..	..	..	250	340	430	530	620	710	800	890	10	
23	..	..	..	..	370	470	580	680	780	880	980	11	
24	..	..	..	..	410	510	640	740	850	960	1,070	11	
25	..	..	..	..	..	560	680	800	930	1,050	1,170	12	
26	..	..	..	..	..	600	730	870	1,000	1,140	1,280	12	
27	..	..	..	..	..	..	790	940	1,090	1,250	1,400	12	
28	..	..	..	..	..	..	840	1,010	1,180	1,350	1,520	13	
29	..	..	..	..	..	..	..	1,070	1,260	1,450	1,650	13	
30	..	..	..	..	..	..	..	1,150	1,350	1,560	1,780	14	

In the conversion of cubic feet into cords of pulp wood closely piled, peeled, dry and when the sticks are more than 12 inches in diameter, split, the number of cubic feet of solid wood required to make a cord, varies according to the diameter of the trees. Large wood piles more compactly than small, consequently a cord of such wood contains a larger number of cubic feet solid wood than a cord of wood from small trees. Table 5 shows the number of cubic feet of closely piled, peeled and split stem wood to three inches in diameter in the top, required to make a cord.

TABLE 5.—*Number of cubic feet of peeled stem wood in trees of different diameters to a cord of 160 cubic feet.*

Diameter of trees breast-high	Number of cubic feet of solid wood to a cord		Per cent of solid wood in a cubic foot
	of 128 feet	of 160 feet	
Below 7 inches.....	81.3	101.6	62.6
7 to 9 inches.....	88.3	110.4	69.
10 inches and over.....	91.4	113.6	71.

Table 6 gives the volume in cords of 160 cubic feet of stem wood only, peeled, to three inches.

TABLE 6.—*Volume in cords of 160 cubic feet, of second growth trees of yellow poplar, stem wood, peeled, only to 3 inches in diameter.*

Diameter breast- high Inches	Height of trees — Feet							
	40	50	60	70	80	90	100	110
	Cords of 160 feet							
5	.018	.025	.032	.038	..	..	..	..
6	.027	.033	.042	.052	.060	..	..	..
7	.034	.043	.053	.064	.074	.083	..	..
8	.043	.055	.067	.080	.091	.103	.117	..
9	.053	.068	.084	.099	.113	.127	.140	..
10	.065	.085	.103	.121	.138	.153	.169	.187
11	.078	.103	.126	.147	.166	.185	.205	.226
12	.093	.125	.152	.176	.199	.222	.245	.269
13	.108	.150	.180	.208	.235	.263	.289	.316
14	..	.178	.212	.243	.274	.305	.336	.365
15	..	.210	.246	.280	.314	.349	.384	.418
16	..	..	.283	.319	.356	.393	.433	.470
17	..	..	.322	.361	.400	.440	.483	.523
18	..	..	..	.405	.446	.489	.532	.575
19	..	..	..	.450	.493	.538	.583	.628
20	..	..	..	..	.540	.587	.633	.682

Table 7 gives the number of mine props which can be cut from trees of different heights and diameters.

TABLE 7.—*Second-growth yellow poplar. Volume table for mine props from trees of different heights and diameters.*

Diameter breast-high	Height — Feet						
	40	50	60	70	80	90	100
Inches	Number of sections 5 ft. long and more than 5 in. inside bark at top						
5	..	..	2	..	..	..	..
6	2	3	4	..	..	..	..
7	2	4	5	5	7	..	..
8	3	5	6	7	8	..	..
9	4	5	6	8	9	..	..
10	4	6	7	8	10	..	..
11	4	6	7	9	10	10	..
	Number of sections 5 ft. long and more than 7 in. inside bark at top						
5	..	..	..	..	..	..	..
6	..	..	..	..	..	..	..
7	..	..	..	1	1	..	..
8	1	1	2	2	2	..	..
9	2	3	3	4	5	..	..
10	2	4	4	5	6	..	..
11	3	4	5	6	7	7	..
12	..	..	6	7	8	9	..
	Number of sections 7 ft. long and more than 5 in. inside bark at top						
5	..	..	1	..	..	..	..
6	1	2	3	..	..	..	..
7	2	3	3	4	5	..	..
8	2	3	4	5	5	..	..
9	2	4	4	5	6	..	..
10	3	4	5	6	7	..	..
11	3	4	5	6	7	8	..
	Number of sections 7 ft. long and more than 7 in. inside bark at top						
5	..	..	..	..	..	..	..
6	..	..	..	..	..	..	..
7	..	..	..	..	1	..	..
8	..	1	1	1	1	..	..
9	1	2	2	3	3	..	..
10	1	2	3	4	4	..	..
11	2	3	4	4	5	5	..
12	..	..	4	5	6	6	..

Yield.—Throughout Tennessee, in old pastures and in hollows on cut-over land, there are stands of second growth poplars. These are sometimes pure, consisting only of poplars, but as a rule contain varying proportions of other species, which are chiefly pine, oak, locust, and chestnut. Yield tables show the probable volume per acre of such stands at different ages, as well as the possibilities of plantations.

As in the case of individual trees, the growth of trees in such stands varies widely with the quality of the soil. Table 8 gives the yield per acre under different conditions of growth of pure unthinned stands of yellow poplar at different ages, in board feet from all trees 10 inches and over in diameter breast-high, outside of bark, and the cord wood suitable for pulp in small trees and tops. Stands which have been thinned and otherwise cared for should give larger yields than shown.

TABLE 8.—Column "a" includes the saw timber from trees 10 inches and over; column "b", the cordwood in trees 5 to 9 inches which are too small to be cut into saw timber; column "c", the cordwood in the tops of trees in column "a"; column "d", the sum of columns "b" and "c"; column "e", the cordwood in column "a" converted into cordwood plus columns "b" and "c".

Age of stand	Yield of saw timber from trees 10 in. and over in diameter outside bark breast- high	Yield of cordwood in connec- tion with saw timber			Yield in cords of all the stem wood in all the trees 5 inches and over in stand
		From trees 5 to 9 in. in diameter outside bark breast- high	In tops of trees 10 inches and over in diam- eter ter breast- high	Total yield of cordwood in addi- tion to saw timber	
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>
Years	Board feet	Long cords	Long cords	Long cords	Long cords
Good condition of growth					
20	5,490	11.4	1.1	12.5	19
30	14,310	12.1	2.6	14.7	31
40	21,780	11.2	3.2	14.4	41
50	28,440	9.4	4.0	13.4	49
60	34,020	7.5	4.2	11.7	56
Average conditions of growth					
20	540	9.5	0.3	9.8	13
30	7,020	12.0	1.8	13.8	23
40	13,950	12.2	2.7	14.9	31
50	20,160	11.4	3.4	14.8	37
60	25,830	10.0	3.7	13.7	43
Poor condition of growth					
30	1,800	10.5	1.0	11.5	17
40	7,920	12.0	1.8	13.8	23
50	13,680	12.2	2.3	14.5	28
60	18,630	11.5	3.0	14.8	..

Graded volume tables.—With the increase in the diameter of the tree there is also an increase in the width of the boards which can be sawed from the logs; a decrease in the amount of sapwood on the boards, and in the proportion of knots to the total width of boards and even in the actual number of knots. Yellow poplar lumber increases in value as the boards become wider, as the proportion of heartwood increases and as

the number and size of the knots decrease. Consequently, lumber sawed from large trees is worth more per thousand feet than that from small trees which are growing under the same conditions.

Table 9 gives the per cent of the different grades of lumber sawed from trees of yellow poplar of different diameters, using a circular saw which takes $\frac{1}{4}$ -inch kerf and sawing the boards $1\frac{1}{8}$ inches thick to allow for shrinkage. This table, above a diameter of 12 inches, is derived from one prepared by E. A. Braniff, showing the yield of trees of yellow poplar when sawed with a band saw taking seven cuts to the inch. Mr. Braniff's figures were obtained at a mill in eastern Tennessee. There is a constant increase in the proportion as well as in the amount of the higher grades with trees of a larger diameter and a corresponding decrease in the proportion of the less valuable grades.

TABLE 9.—Percentage of different grades of lumber sawed out of yellow poplar trees of different diameters. Diameters 13 inches and over, by E. A. Braniff.

Diameter breast high Inches	Nos. 1 and 2	Saps and selects	Wide box	No. 1 common Per cent	No. 2 common	No. 3 common	Total yield per tree Bd. ft.
9	..	..	..	4	74	22	30
10	..	..	..	8	70	22	41
11	..	..	..	11	66	23	54
12	..	1	..	12	64	23	68
13	..	2	..	14	62	22	86
14	..	3	..	14	61	22	117
15	..	4	..	15	59	22	144
16	..	5	..	16	57	22	180
17	1	6	..	17	55	21	210
18	2	7	..	18	52	21	248
19	3	8	..	19	50	20	293
20	4	9	..	20	47	20	342
21	5	10	..	20	45	20	395
22	6	11	..	21	43	19	456
23	8	12	1	21	40	18	521
24	9	13	1	22	38	17	591
25	11	13	1	22	36	17	669
26	12	13	2	23	34	16	749
27	14	13	2	23	33	15	833
28	16	12	3	23	31	15	932
29	19	11	4	23	29	14	1,030
30	20	11	4	23	28	14	1,125
31	22	10	5	23	27	13	1,227
32	23	10	5	23	26	13	1,326
33	24	9	5	23	26	13	1,427
34	26	9	6	22	25	12	1,533
35	28	8	6	22	24	12	1,649
36	29	8	6	22	23	12	1,742

The percentage of grades given in trees of diameter above 14 inches applies only to old growth trees. As a rule, small trees in second growth stands, 14 inches or less in diameter breast-high, saw out largely lumber of the grades No. 2 common and cull, together with smaller amounts of No. 1 common and sap grades than are given in the table. Clean stemmed second growth trees which are from 14 to 20 inches in diameter saw out a far larger, but somewhat variable, proportion of clear saps and a much smaller proportion of No. 1 and 2 grade than old forest trees of the same diameter.

Table 10 shows the amounts of the different grades of lumber sawed from trees of yellow poplar of different diameters and their values at Chattanooga, Knoxville, Nashville, Bristol, and other large shipping points in Middle and East Tennessee. Prices at points in West Tennessee are usually about 25 cents per 1,000 board feet lower.

The following prices of the different grades are used in determining the values of the lumber in totals:

Nos. 1 and 2.....	\$53.50 per 1,000 board feet
Saps and selects.....	38.50 per 1,000 board feet
Wide box	40.00 per 1,000 board feet
No. 1 common.....	29.00 per 1,000 board feet
No. 2 common.....	18.00 per 1,000 board feet
No. 3 common.....	13.25 per 1,000 board feet

These were the prices in carload lots for July, 1913, at the important lumber centers of Tennessee.

TABLE 10.—Amounts and values of the different grades of lumber saved out of yellow poplar trees of different diameters, 1/4-inch saw kerf. Values f. o. b. Nashville and other important points.

Diameter breast- high Inches	No. 1 and 2		Saps and selects		Wide box		No. 1 common		No. 2 common		No. 3 common		Total volume value		Total per tree	
	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value	Bd. ft.	Value
9	..	..	..	..	..	..	1	\$ 0.03	22	\$0.40	7	\$0.09	30	\$ 0.52	41	.73
10	..	..	..	..	..	..	3	.09	29	.52	9	.12	41	.73	54	.98
11	..	..	..	..	..	..	6	.17	36	.65	12	.16	54	.98	68	1.27
12	..	..	1	\$0.04	..	..	8	.23	44	.79	16	.21	68	1.27	86	1.63
13	..	..	2	.08	..	..	12	.35	53	.95	19	.25	86	1.63	117	2.23
14	..	..	4	.15	..	..	16	.46	71	1.28	26	.34	117	2.23	144	2.82
15	..	..	6	.23	..	..	22	.64	85	1.53	32	.42	144	2.82	180	3.57
16	..	..	9	.35	..	..	29	.84	103	1.85	40	.53	180	3.57	210	4.32
17	2	\$ 0.11	13	.50	..	..	36	1.04	116	2.09	44	.58	210	4.32	248	5.24
18	5	.27	17	.65	..	..	45	1.31	129	2.32	52	.69	248	5.24	293	6.42
19	9	.48	23	.89	..	..	56	1.62	147	2.65	59	.78	293	6.42	342	7.71
20	14	.75	31	1.19	..	..	68	1.97	161	2.90	68	.90	342	7.71	395	9.15
21	20	1.07	40	1.54	..	..	79	2.29	178	3.20	79	1.05	395	9.15	456	10.83
22	27	1.44	50	1.93	..	..	96	2.78	196	3.53	87	1.15	456	10.83	521	13.08
23	42	2.25	63	2.43	5	\$0.25	109	3.16	208	3.74	94	1.25	521	13.08	591	15.25
24	53	2.84	77	2.96	6	.30	130	3.77	225	4.05	100	1.33	591	15.25	669	17.77
25	74	3.96	87	3.35	7	.35	147	4.26	241	4.34	114	1.51	669	17.77	749	20.47
26	90	4.82	97	3.73	15	.75	172	4.99	255	4.59	120	1.59	749	20.47	833	23.45
27	117	6.26	108	4.16	17	.85	192	5.57	275	4.95	125	1.66	833	23.45	932	26.95
28	149	7.97	112	4.31	28	1.40	214	6.21	289	5.20	140	1.86	932	26.95	1030	31.05
29	196	10.49	113	4.35	41	2.05	237	6.87	299	5.38	144	1.91	1030	31.05	1125	34.33
30	225	12.04	124	4.77	45	2.25	259	7.51	315	5.67	158	2.09	1125	34.33	1227	38.50
31	270	14.45	123	4.74	61	3.05	282	8.18	331	5.96	160	2.12	1227	38.50	1427	45.43
32	305	16.32	133	5.12	66	3.30	305	8.85	345	6.21	172	2.28	1427	45.43	1649	55.03
33	342	18.30	128	4.93	71	3.55	328	9.51	371	6.68	186	2.46	1649	55.03	1742	58.72
34	399	21.35	138	5.31	92	4.60	337	9.77	383	6.89	184	2.44	1742	58.72	198	2.62
35	462	24.72	132	5.08	99	4.95	363	10.53	396	7.13	198	2.62	198	2.62	209	2.77
36	505	27.02	139	5.38	105	5.25	283	11.11	401	7.22	209	2.77	209	2.77	209	2.77

Increase in value with size.—Table 11 shows the value per 1,000 board feet of lumber sawed from trees of different diameters and the value of lumber sawed from each tree f. o. b. Knoxville, Tennessee, and the stumpage value per tree under operating expenses of \$10, \$12, \$14, and \$16 per 1,000 board feet.

TABLE 11.—*Stumpage values of trees of different sizes under different costs of operation and the stumpage value per 1,000 feet of the lumber from such trees.*

Diameter breast- high Inches	Value of lumber per 1,000 ft. f. o. b. Nash- ville	Value of stumpage per 1,000 Bd. ft. costs per 1,000 Bd. ft.				Value of stumpage per tree operating costs per 1,000 Bd. ft.			
		\$10	\$12	\$14	\$16	\$10	\$12	\$14	\$16
9	\$17.33	\$ 7.33	\$ 5.33	\$ 3.33	\$ 1.33	\$ 0.22	\$ 0.16	\$ 0.10	\$ 0.04
10	17.80	7.80	5.80	3.80	1.80	.32	.24	.16	.08
11	18.15	8.15	6.15	4.15	2.15	.44	.33	.22	.11
12	18.68	8.68	6.68	4.68	2.68	.59	.45	.32	.19
13	18.95	8.95	6.95	4.95	2.98	.77	.60	.43	.26
14	19.06	9.06	7.06	5.06	3.06	1.06	.83	.59	.35
15	19.58	9.58	7.56	5.56	3.56	1.38	1.09	.80	.51
16	19.83	9.83	7.83	5.83	3.83	1.77	1.41	1.05	.69
17	20.57	10.57	8.57	6.57	4.57	2.22	1.80	1.30	.96
18	21.13	11.13	9.13	7.13	5.13	2.76	2.26	1.77	1.28
19	21.91	11.91	9.91	7.91	5.91	3.49	2.90	2.32	1.74
20	22.64	12.64	10.64	8.64	6.64	4.29	3.61	2.92	2.23
21	23.16	13.16	11.16	9.16	7.16	5.20	4.41	3.62	2.83
22	23.75	13.75	11.75	9.75	7.75	6.27	5.36	4.45	3.54
23	25.11	15.11	13.11	11.11	9.11	7.87	6.83	5.79	4.75
24	25.80	15.80	13.80	11.80	9.80	9.34	8.16	6.98	5.80
25	26.56	16.56	14.56	12.56	10.56	11.08	9.74	8.40	6.06
26	27.33	17.33	15.33	13.33	11.33	12.98	11.48	9.98	8.48
27	28.15	18.15	16.15	14.15	12.15	15.12	13.45	11.79	10.13
28	28.92	18.92	16.92	14.92	12.92	17.63	15.77	13.90	11.03
29	30.15	20.15	18.15	16.15	14.15	20.75	18.69	16.63	14.57
30	30.52	20.52	18.52	16.52	14.52	23.08	20.83	18.58	16.33
31	31.38	21.38	19.38	17.38	15.38	26.23	23.78	21.32	18.86
32	31.73	21.73	19.73	17.73	15.73	28.82	26.17	23.52	20.87
33	31.84	21.84	19.84	17.84	15.84	31.16	28.31	25.45	22.59
34	32.85	22.85	20.85	18.85	16.85	35.03	31.96	28.90	25.84
35	33.37	23.37	21.37	19.37	17.37	38.54	35.24	31.94	28.64
36	33.71	23.71	21.71	19.71	17.71	41.30	37.82	34.33	30.84

Operating expenses embrace the costs of logging, sawing, selling, grading, insurance, carrying stock, carrying timber, salaries and all overhead charges; cost of hauling or transporting from mill to railroad; an allowance for difference in freight to compensate for the difference in the price

of lumber at points which have a higher freight rate than the lumber centers, and includes all profits in operating and selling. Operating expenses vary with the accessibility of timber, class of operation, and the ability of the operators. The average expense at present in producing yellow poplar in Tennessee is above \$14 per 1,000 board feet. The allowance for difference in freight rates amounts to 30 cents per 1,000 board feet for each difference of 1 per cent per 100 pounds in the freight rate. This difference should be deducted from the value shown in Table 11 when the freight rate is less than the rate from the lumber centers, and added when the freight rate is higher. The prices given for lumber are based on well graded and well sawed stock in car lots. When lumber is sold through brokers and commission men the prices are from 5 to 8 per cent. less.

The value of the yellow poplar trees in a stand are determined by ascertaining by measuring and tallying the number of trees of each diameter, and multiplying these numbers by the value of trees of the respective diameters under the appropriate cost of operating.

Increase in price.—In addition to the increase in volume and increase in quality, which accompanies growth, due to increase in the proportion of higher grades, there is a third but irregular increase in value due to increase in price. Since this increase varies with the proportion of the different grades of lumber which can be sawed from the tree, it can be calculated only by considering the increase in the price of these component grades. During the past 20 years there has been a greater per cent. of increase in the prices of lower grades than in those of the higher grades. The higher grades, consisting of Nos. 1 and 2, and saps, have increased in price at Knoxville about 3.7 per cent, compounded per year; lower grades No. 2 common and No. 3 common at a rate of about 4.9 per cent. a year. This increase in the price of the lower grades should be considered as one of the elements of increased value in plantations and in young stands which contain a large proportion of poplar trees and which are being managed as investments. Second growth trees of small saw log size yield largely No. 2 common grade of lumber. The rate per cent. of increase in the price of this grade during the past 10 years indicates the probable rate of increase in the price of small sap trees during the next 10 or 20 years. In 1903 this grade sold for \$13 per 1,000 board feet at Tennessee points. Under an operating cost of \$12 per 1,000 board feet this grade at that time had a stumpage value of \$3 per 1,000 feet; its stumpage value in 1913 under an operating cost of \$12 per 1,000 board feet is \$5. The rate of increase in value during the decade was 5.2 per cent a year. If this rate of increase in price continues for the next two or three decades, and is considered in connection with the increase in the value of stands and individual trees by growth and quality, there is an

assurance of an excellent rate of profit from the management of pure stands of young trees and from plantations.

Table 12 shows the rate per cent. of increase in the price of the most important grades of lumber at the chief Tennessee shipping points:

TABLE 12.—*Rate per cent., compound, increase in the price of the important grades of yellow poplar lumber at Tennessee points during the 20-year period 1893-1913.*

Grades	Price in 1893	Price in 1913	Rate per cent. of increase in price compound
No. 1 and 2.....	\$25.00	\$53.00	3.9
Saps and selects.....	19.00	38.50	3.6
No. 1 common.....	16.00	29.00	3.
No. 2 common.....	7.00*	18.00	4.8
No. 3 common.....	5.00*	13.25	5.

Estimated stumpage has increased at a higher rate than lumber. A 28-inch tree may be regarded as of average size in operation during the past 20 years. In 1893 lumber from trees of this diameter had an f. o. b. value of \$11.86 per 1,000 board feet. No logs which would cut largely No. 2 and No. 3 common would be taken to the mill. The average cost of operation at that time may be placed at \$10.70 per 1,000. In 1913, on account of the increase in wages and supplies, the cost of operation under the same conditions is \$16 per 1,000 board feet. In 1913 the f. o. b. value of lumber from an average tree 28 inches in diameter breast-high is \$28.92 per 1,000 feet, at important shipping points in Tennessee. These figures give stumpage values of \$1.16 per 1,000 board feet in 1893; and \$12.92 per 1,000 board feet in 1913. The increase in value of the stumpage of a tree of this diameter has been at a rate of 13 per cent., compounded, a year. Such a rate will scarcely continue for the next decade, since the tendency of the rate of increase is to decline as the base on which it is calculated becomes larger, although the actual amount of increase may be the same.

INCREASING THE YIELD FROM TIMBER LAND.

The rate of growth of trees and the yield of timberland are as a rule greatly overestimated by owners. Their opinions have been formed as a result of the method of cutting which has been used on many tracts of timber. While it is true that many tracts have been cut over several times, only a small portion of the merchantable timber was cut in the earlier operations. In the first cutting, as a rule, the larger and more valuable trees were taken to 24 or 30 inches in diameter. A subsequent cutting removed some of the inferior large trees, and cut the more valua-

able trees to 20 inches; and a third one, made probably 20 years after the first, removing a lower grade, cut to 16 inches. No cutting has thus far removed all of the stand. So long as there remains a large number of trees 14 to 20 inches in diameter, the annual growth in board feet per acre is large, and if cutting is not below a diameter of 18 or 20 inches, comparatively heavy yields can be obtained every 15 or 20 years from the same tract. As soon, however, as cutting is to a diameter below 10 inches, not only must a very much longer time elapse before another profitable cutting of large timber can be obtained, but there is a loss in converting into lumber, since, while the waste of kerf and slabs in the case of larger timber is only 50 per cent., it is 75 per cent. in the case of small timber. While cutting to too small a diameter over an entire tract is to be avoided, other requirements must be considered.

There is no single operation or process the use of which will develop the maximum earnings of a forest which contains yellow poplar. The following are the most important points to consider in seeking to develop and maintain on a tract a high yield of yellow poplar, and to secure a product of high value.

Management.

- (1) Developing a form of stand which permits intensive operations.
- (2) Cutting trees only at or above a size which indicates maturity.
- (3) Obtaining full-stocked stands by preventing fires and by regulating grazing.
- (4) Eliminating species of low value from stands.
- (5) Thinning young stands in order to accelerate growth.

Better Utilization.

- (6) Reduction of waste and closer utilization of timber.
- (7) Selling timber in its most profitable form.

MANAGEMENT.

Developing a desirable form of stand.—By procuring a suitable form of stand, the conditions are obtained which are best suited for the replacement and most rapid growth of the valuable species in the stand, since yellow poplar requires a large amount of light for its establishment and growth, and its most rapid development takes place in even-aged stands and groups.

Sprout forms.—While young trees sprout sufficiently to be managed as sprout stands, this form of stand can be used only for the production of small timber, such as pulp wood, and is advisable only on good sites where pure stands of yellow poplar can be grown, or mixtures of yellow poplar

with chestnut, red oak, locust, and other species which sprout. The rotation or period required for the maturity of a coppice stand is from 20 to 35 years. Sprout trees which are much older than 35 years, frequently become so defective at the butt that they break off. Sprout stands should be even-aged or in even-aged groups.

High forest forms.—For the production of saw timber, yellow poplar can be managed only with seedling trees in high forest. Of the different high-forest forms, yellow poplar is well suited only to even-aged stands, in which all the trees in one cutting unit or block are of the same age or approximately so; or to a group or strip form in which the trees occur in even-aged strips or groups. The groups or strips can be made so small as to develop a group or strip selection form. Such stands can be either pure or mixed. The single tree selection form of forest (which consists of trees of all ages mixed in the stand) with its more restricted light conditions is not so well adapted to securing the replacement of yellow poplar. The group and strip forms seem to particularly meet the requirements of yellow poplar in mountain forests.

(1) The advantage of the group or strip forms are that profitable cuttings of large timber can be made in the same cove or valley at short intervals. When the growth is rapid, the intervals between cuttings might not exceed 15 years.

(2) Since the mature groups are cut clean, there is no breakage of small timber in felling as is the case when culling and simple selection is practiced.

(3) Large timber can be logged to loaders by cable with less serious breakage of small trees.

(4) Restocking with yellow poplar and white pine is more easily obtained in the center of openings, while nearby oaks seed up the edges.

(5) The soil is better protected from erosion than it is in the case of clean cutting, and there is less danger of destruction by fire on the cut-over areas. The intermixture of species with heavy crowns, likewise assures protection of the soil from drying winds.

(6) With groups of young timber adjacent to groups which are mature, more intensive management can be practiced than is possible in the case of selection stands. It is possible to make thinnings in groups of immature trees, thus freeing the larger trees in these groups, and accelerating their growth. At the same time, the small timber which is removed in thinnings, and which otherwise would be lost, can be utilized.

Applying this method of cutting to a farm forest of 100 acres in which an ideal form of stand has already been developed, there would be one group of trees which would be mature and which would be cut that year or during the cutting period, which might be as long as 10 years. If 50 years

were required for the trees to fully mature, one-fifth of the forest, or 20 acres, would be mature and ready to be cut during this period of 10 years. One-fifth, or 20 acres, would have been cut over during the preceding 10 years, and would have restocked in small seedlings; 20 acres would bear a stand with an average age of 15 years. The stand on 20 acres would have an average age of 25 years; while that on 20 acres would have an average age of 35 years. At the same time that saw timber was being cut in the mature stand, large poles would be removed in thinning the 35-year-old tract; small poles would be removed in thinning the 25-year-old stand, and small saplings in thinning the 15-year-old stand. This would insure a continuous supply of large timber as the areas of the different age-classes matured. At the same time there is always an area in process of restocking equal to that which is being cut over. In a large tract, each cove might take the place of the 100-acre tract, and a suitable grouping of age classed be obtained in it.

In developing groups, they may vary in size from 100 feet square to two or three acres in extent. Strips, which in a mountainous region might be located up and down the slope, may be from three to five chains wide, or as might often be advisable in the mountains, they might coincide with the limits of narrow coves or hollows. On small tracts, such as farm forests, blocks or cutting units which are designated with the object of facilitating management, might be so small as to form in reality a group selection form.

Natural forests seldom occur in the forms which have been recommended, but the tendency is for even-aged stands to result from clean cutting. There is also a tendency in the mountainous portions of Tennessee for the formation of even-aged second growth stands in the coves and hollows, where these are cut clean and for the formation on the slopes of even-aged groups or strips of young timber alternating with groups or strips of old timber which were not felled, either because they were less accessible or because they were largely composed of inferior species or low-grade trees. In extensive operations, this last condition forms a basis for ultimate conversion into a form of groups or strips which is adapted to logging at frequent intervals. It is impossible to convert from the present irregular form of stand without some slight cost; and in the case of large and inaccessible tracts on which operating charges are high, conversion must be affected gradually in order to reduce the cost. A compromise, consequently, is necessary. The owner foregoes a part of his present profit with the expectation of greatly increasing the earning power of his land at the date when future cuttings are made. A tree is left in one place which could be removed at a slight present profit, but which is increasing in value at a high rate. Another tree

is taken which offers less profit, because it is declining in value and interfering with the growth of valuable young timber. The action in both cases looks toward the resultant form of forest and the profit accrues to the date of future cuttings. It is as desirable that a definite form of forest be developed in the management of small tracts of from 50 to 100 acres as in the case of large tracts of 10,000 or more acres. While it is often impossible on a large tract, on account of increasing logging costs, to cut for the best future interests of the forest, there are no such restrictions in the case of small tracts on farms. The farmer can generally use his own teams and can log carefully, cutting a portion of this tract each year. In this way, he is in a position in a few decades to obtain a form of forest which will produce more profitably a much higher yield than is possible in the case of large and inaccessible tracts. The tendency of yellow poplar to occur in groups in second growth stands is shown.

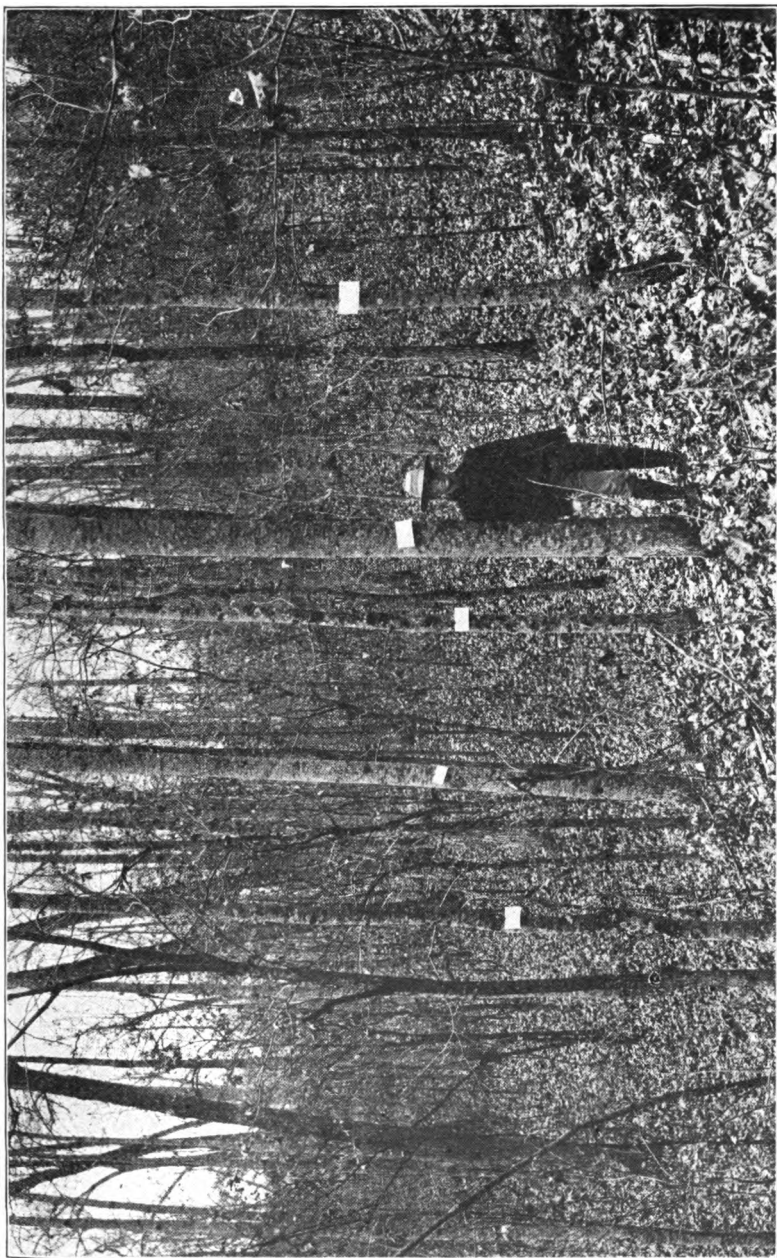


FIG. 4. Group of yellow poplar poles in a crowded stand of mixed species 20 to 30 years old. The crowding should be relieved by cutting some of the middle size (intermediate) trees and the defective dominant (large) trees. The well shaped dominant trees should not be cut at the present time, neither should the suppressed trees which, while they can not be expected to make sawlogs, still serve a useful purpose in shading the soil and maintaining its moisture supply. This illustrates the tendency of yellow poplar to form groups. (Photo Forest Service.)

MATURITY OF TIMBER.

Single trees in mixed stands.—Single trees of yellow poplar can be considered mature financially when their annual rate of increase in value becomes equal to the current rate of interest on money. If timber is held after the rate of increase in value falls below the interest rate, there is a loss, since if the timber had been sold, the proceeds could have been invested as loans at the current interest rate on money. Table 13 shows the rate of increase in value by growth of trees of yellow poplar under different costs of logging while increasing one inch in diameter. This does not include the increase in price, and the current increase in price should always be considered in connection with this table. While price increase of large poplar has been very high in the past, the rate will probably decline in the future.

The rate of increase in the price of second growth for the past decade has been only about 5 per cent. Although yielding well above the current rate of interest, if the present rate of increase in price is also considered, 16 inches might be considered a diameter for cutting when the cost of operating is low; 18 inches when the cost is about \$13 per 1,000 board feet; and 20 inches when the cost of operating is more than \$15 per 1,000 board feet. The rate of growth of the timber also affects its increase in value. On the best sites, such as very fertile coves where poplar will produce four and five logs 16 feet long, including the cull top log, these diameters might be two inches larger respectively. On very poor sites where only two and three logs can be cut from the trees, and those are sappy, knotty, or otherwise low grade, the diameter for cutting can be 15 inches breast-high, under a low cost of operation, 17 inches under an average cost, and 19 inches under a high cost of operation.



FIG. 5. A virgin stand of mixed hardwoods which contains a large proportion of yellow poplar. The merchantable trees in this stand of other species, as well as yellow poplar, are mostly of very large size. The small trees in the stand are suppressed or specimens of small tolerant species. This stand requires cutting clean except for seed trees. It will be necessary to destroy the heavy undergrowth of trees and shrubs which are tolerant of shade in order to be assured of a large proportion of yellow poplar in the restocking. (Photo Forest Service.)

TABLE 13.—*Time required for trees of yellow poplar to grow one inch in diameter, under average conditions, and annual rate per cent. of increase in value by growth.*

Diameter of tree breast- high	Time required to grow 1 inch in diameter	Operating costs \$12 a 1,000 board feet		Operating costs \$16 a 1,000 board feet	
		Stumpage value per tree	Rate of increase in value a year	Stumpage value per tree	Rate of increase in value a year
Inches	Years	Value	Per cent.	Value	Per cent.
9	..	.16	..	.04	..
10	3.5	.24	12.3	.08	21.9
11	4.0	.33	8.3	.12	13.3
12	4.0	.45	8.1	.19	10.6
13	4.0	.60	7.5	.26	8.1
14	4.0	.83	8.4	.35	7.7
15	4.5	1.09	6.2	.51	8.7
16	5.0	1.41	5.3	.69	6.2
17	5.5	1.80	4.5	.96	6.2
18	5.5	2.26	4.2	1.28	5.4
19	5.5	2.90	4.6	1.74	5.7
20	6.0	3.61	3.7	2.23	4.2
21	7.0	4.41	2.9	2.83	3.5
22	7.0	5.36	2.8	3.54	3.3
23	8.0	6.83	3.1	4.75	3.7
24	9.0	8.16	2.0	5.80	2.2
25	9.0	9.74	2.0	7.06	2.2
26	9.0	11.48	1.8	8.48	2.0
27	10.0	13.45	1.6	10.13	1.8
28	10.0	15.77	1.6	11.03	0.9

Determination of the future yield in mixed selection stands.—In connection with the management of selection stands of mixed forest, it is frequently desirable to know what yield of yellow poplar can be expected from a tract at different future periods, or what number of poplar trees of different diameter classes it would be necessary to have growing, to provide for a sustained yield (normal distribution of age classes). The following table enables this to be determined, if the poplar in the stand is in unthinned groups. It shows for average conditions of soil what should be the relative number of trees of different diameter classes to an acre, to provide for a sustained annual yield of 430 board feet on average quality sites, which would be the yield from fully stocked acres of pure stands if each diameter class occupies the same proportional crown area.



FIG. 6. A second-growth stand of mixed hardwoods which contains a large number of medium sized yellow poplars. A diameter limit (selection system) for cutting could advantageously be applied to this stand since it contains many small and medium sized trees. Openings should be made sufficiently large, however, by group cutting to ensure the replacement of poplar on them, since the site is evidently well suited to the growth of this species. The absence of young growth indicates that the present forest cover is dense. (Photo Forest Service.)

Number of trees in different diameter classes per acre, required to obtain a continuous yield from a fully stocked group selection stand of pure poplar.

Diameter classes breast-high Inches	Number of trees per acre on av- erage quality sites	Approximate per cent of each diameter class which should exist in a normal stand
2- 4	280	54.00
5- 8	151	30.00
9-12	57	11.00
13-16	19	4.00
17-20	5	1.00
above 20	1	.30
Total per acre	513	

Since this table is based on fully stocked pure stands, it is necessary in the consideration of a mixed stand to ascertain the average number of trees of the different diameter classes per acre. The relation of this number in each diameter class to the corresponding table number gives the proportional annual yield which is to be expected from this diameter class when mature, that is, when larger than 20 inches in diameter.

If in place of 19 trees to the acre, in the 13 to 16 inch diameter class there were 6 trees, the proportion of stocking would be 6-19, so far as this diameter class were concerned. The annual yield per acre from a fully stocked stand is 430 board feet, consequently the annual yield with the proportion of stocking given would be $6-19 \times 430 = 135$ board feet. If the average diameter of the 6 trees per acre in this diameter class were 15 inches, it would be (see table 13) 22 years before they were 20 inches and ready to cut. If the interval between cuttings was 10 years the yield would be $10 \times 135 = 1,350$ board feet per acre at that time. This is based on the assumption that poplar trees growing in groups in mixed stands have approximately the rate of growth that they have in pure stands. In strict selection or natural irregular stands in which single trees of yellow poplar compete with slower growing species, the young poplars are more persistent than when they occur in pure groups, and a smaller proportion of them die during the life of the stand.

If such mixed selection stands where the yellow poplar trees occur as single trees, the crown spread of the dominant trees is the most reliable basis to use in determining the proportion which yellow poplar contributes to the stocking of the stand. There is given below the average diameter of the crown spread in feet of dominant and intermediate trees of yellow poplar from 7 to 22 inches in diameter breast-high. Dominant trees,

particularly such trees in thinned stands, have a wider crown spread than is given. The maximum crown spread which can be obtained without unduly developing the crown at the expense of the clear length of stem would be one-half more than is given.

Breast-high diameter of tree, inches	Spread of crown feet	Breast-high diameter of tree, inches	Spread of crown feet
7	11	15	16.5
8	11.6	16	17.2
9	12.4	17	17.9
10	13.3	18	18.6
11	13.7	19	19.4
12	14.4	20	20
13	15.1	21	27.7
14	15.8	22	21.3

Pure stands.—The maturity of pure, even-aged stands is determined by the date at which the largest profit or per cent. is earned on the investment. The investment embraces—

- (1) The value of the soil;
- (2) The cost of establishing the stand, which might consist either in leaving seed trees, or increased cost of logging the old stand, or the cost of seeding or planting;
- (3) The cost of protection, which may be a yearly cost or might be required only while the stand was young, and the interest on such costs;
- (4) Taxes on soil and timber, and the interest on taxes;
- (5) The cost of thinning and cleanings and the interest on such expenses.

The volume of a pure, even-aged stand increases rapidly at first, then more slowly and finally becomes stationary. The value of the timber based on the quality or proportion of grades increases in the same manner. Value increment continues long after the volume of the stand has become stationary.

There is also, as has been explained, a fluctuating increase in price of grades of lumber, which affects the value of stumpage. This is neglected in all calculations, but it should be given careful consideration by owners of stands in fixing the period of cutting. Table 14 shows the cost per 1,000 board feet of growing yellow poplar in pure stands, and the most profitable age at which to cut, when the cost of stocking is \$3 an acre and when the detailed items of expense are as shown. The greatest profit per 1,000 board feet, 49 cents, in excess of all costs and interest, is made by cutting at 35 years of age. At 30 years the profit is 42 cents per 1,000 feet; at 40 years it is 36 cents a 1,000 feet. Price increase is neglected.

TABLE 14.—Second-growth yellow poplar. Most profitable age for cutting unthinned stands for lumber, and the cost per 1,000 board feet of growing timber with natural reproduction. Average sites. Interest rate, 5 per cent; value of soil, \$5 per acre; cost of stocking, \$3 per acre.

Age of stand	EXPENSES IN GROWING TIMBER											
	Cost of land, stocking and protection						Taxes					
	Value of stumpage per acre at end of 5-year period at present prices	Accrued interest on value of land to end of 5-year period	Cost of stocking and interest on it to end of 5-year period	Cost of protection, 5 cents per acre per year, and accrued interest to end of each 5-year period.	Annual for each 5-year period at 1 per cent. on a two-thirds valuation of stand.	Taxes and accrued interest at 5 per cent. to end of each 5-year period.	Taxes at 1 per cent. on land and accrued interest to end of each 5-year period.	Total cost of growing timber to the end of each 5-year period.	Profit or loss in excess of 5 per cent. on the basis of stumpage values.	Cost of 1,000 Bd. ft. of growing stand.	Value per 1,000 Bd. ft. of stand on basis of present prices of lumber.	Per cent. of increase in stumpage values necessary to yield 5 per cent.
Years	Per acre	Per acre	Per acre	Per acre	Per acre	Per acre	Per acre	Per acre	Per acre	Per 1,000 feet	Per 1,000 feet	Per cent
20	\$ 17	\$ 8.27	\$ 7.96	\$ 1.65	\$0.12	\$	\$ 1.65	\$ 19.53	\$*2.53	\$3.83	3.33	..
25	29	11.93	10.16	2.39	.18	0.66	2.39	27.53	1.47	3.03	3.19	..
30	43	16.61	12.96	3.32	.28	1.84	3.32	38.05	4.95	2.95	3.33	..
35	60	22.58	16.55	4.52	.40	3.90	4.52	52.07	7.93	3.19	3.68	..
40	78	30.20	21.12	6.04	.52	7.20	6.04	70.60	7.40	3.64	4.02	..
45	97	39.93	26.95	7.99	.64	12.09	7.99	94.95	2.05	4.24	4.33	..
50	114	52.34	34.40	10.47	.76	19.01	10.47	126.69	*12.69	5.03	4.52	0.2
55	130	68.18	43.91	13.64	.87	28.53	13.64	167.90	*37.90	6.04	4.68	.5
60	143	88.40	56.04	17.68	.95	41.33	17.68	221.13	*78.13	7.30	4.72	.7

*Loss.

Table 15 shows the most profitable diameters and ages at which to cut stands of second growth yellow poplar which have been established without cost and which are unthinned, cutting to different diameters. When the current rate per cent. of increase in value falls below 6 per cent. the stand can be considered as mature. It should be noted that price increment is neglected.

TABLE 15.—*Yellow Poplar. Period of maturity of natural unthinned second-growth stands for saw-timber. Average conditions of growth. Price increment neglected.*

Age of stand	Cutting to 7 inches breast-high				Cutting to 10 inches breast-high		
	Average diameter breast- high of trees in stand Inches	Value of stand per acre saw- timber only	Average annual increase in value	Current rate of increase in value Per cent.	Average diameter of trees over 10 inches in diameter Inches	Value of stand per acre saw-tim- ber only	Average annual increase in value
Years							
20	4.9	\$ 17	\$0.85	23.0	10.5	\$ 6	\$0.30
25	5.9	29	1.16	11.0	11.2	22	.88
30	6.8	43	1.43	8.0	11.7	39	1.30
35	7.6	60	1.71	7.0	12.1	55	1.60
40	8.3	78	1.95	5.0	12.3	73	1.82
45	9.0	97	2.16	4.5	12.6	92	2.04
50	9.5	114	2.28	3.3	12.8	110	2.20
55	10.0	130	2.36	2.7	13.0	126	2.30
60	10.4	143	2.38	2.0	13.1	139	2.33
65	10.8	154	2.37	1.5			

Table 16 shows the cost of growing cordwood and the most profitable age at which to cut cordwood in natural stands. The greatest profit per acre, in addition to interest, is at 25 years, and amounts to \$10.47 an acre. The cost of growing timber at this age is only \$1.45 a cord; much lower than when the stand is either younger or older.

TABLE 16.—*Second-growth yellow poplar. Most profitable age for cutting cordwood in unthinned natural stands, and the actual cost per cord of growing it with natural reproduction. Cost of growing as given in Table 14.*

Average conditions of growth.					
Age of stand Years	Yield per acre in cords of 160 cord feet of peeled stem wood Cords	Value of stand at \$2.00 a cord stumpage	Total cost per acre of growing stand	Profit per acre at any period	Cost per cord of growing timber
20	13	\$26	\$ 19.53	\$ 6.47	\$1.50
25	19	38	27.53	10.47	1.45
30	23	46	38.05	7.95	1.65
35	27	54	52.07	1.93	1.93
40	31	62	70.60	loss 8.60	2.28
45	34	68	94.54	loss 26.54	2.78
50	37	74	126.69	loss 52.69	3.42
55	40	80	167.90	loss 87.90	4.20
60	43	86	221.13	loss 135.13	5.14

GENERAL INSTRUCTIONS.

Protection.—It is necessary to protect from fire and cattle, areas which are in process of stocking with yellow poplar, young stands, and plantations of yellow poplar. This species is extremely sensitive to fire, particularly to early spring fire, until the bark becomes thick and rough. In the case of large areas, as of cut-over land, patrol during spring and in autumn until the newly fallen leaves are thoroughly compact and moist, is the most effective method of preventing fires. It is sometimes possible, particularly in the case of small tracts or single coves, to isolate by means of fire lines, but these should never be exclusively relied upon. It is generally desirable to lop the under limbs of tops of felled trees in order to bring the trunks in close contact with the soil and hasten their decay. Unless there is a large amount of pine or hemlock (spruce pine) slash, the piling and burning of brush is not desirable, since it destroys humus. When large tracts are being grazed, it is necessary either to herd cattle to pre-

vent destruction of small yellow poplar seedling, or to fence areas on which the young growth could be injured.

Unless plantations are protected, the destruction of a part of the stand is likely to result in understocking. The results of understocking are: short-bodied and scrubby trees, the stems being set with numerous large knots so that the lumber is low grade; and in spite of the relatively large diameters of the individual trees a low yield per acre.

Elimination cuttings.—In natural stands of yellow poplar on cut-over land there will often be a very large proportion of low grade species. When these are rapid growing and might seriously interfere with the growth of the poplar, or entirely crowd it out, it is necessary to eradicate them. The material which is cut in this manner often will have no sale value, the cutting being made entirely for the benefit of the mature stand. Such cuttings can sometimes be combined with thinnings



FIG. 7. A pole stand of hardwoods, containing much yellow poplar killed by a severe spring fire. Note sprouts around bases of trees.

Thinnings.—Thinnings are made for the purpose of accelerating the growth of the remaining trees in a stand. They cover two periods. Those which are made in very young stands of sapling and pole size, the result

of which, in addition to lessening overcrowding, is the elimination of trees of undesirable species from the stand. The smaller trees with the poorest formed stems should be removed. Thinnings in young stands should be light, but should be repeated as soon as the crowns of the trees have again become so close together that they interfere. The crowns will seldom touch after the trees have reached small-pole size. Thinnings of this character do not retard height growth or materially interfere with the cleaning of the stem of branches. Thinnings in young stands should never be severe enough to permit the development of large branches. (Fig. 8.)

The second period in thinning is after the stand has reached the large-pole stage and the trees, according to site, are from 80 to 110 feet in height. Clear length of stem has already been developed, and but slight additional growth in height will take place. The best trees should be isolated. These will soon form large crowns and rapid growth in diameter will take place. Additional diameter means not only increased volume, but a higher proportion of upper grades. The diameter of the trees is more important than their number. It will be far more profitable to have 70 trees per acre which have average diameters of 20 inches than 160 trees which have diameters of 15 inches. The 20-inch trees have a stumpage value of \$3.61 each under an operating cost of \$12 per 1,000 board feet, or \$252.70 an acre. The 15-inch trees have a stumpage value of 83 cents each or only \$132.80 an acre. The yield in board feet is approximately the same in both cases—about 23,000 feet per acre. (See Fig. 1.)

The trees removed in thinning from stands after they have passed the sapling stage, should pay for all thinnings. Even-aged second growth stands have a form of forest which requires thinning in order to develop their maximum yields. It is impossible for lumbermen economically to apply thinnings on a large and rough tract, until a suitable form of forest shall have been developed. But second growth stands, owned by farmers or others who live on their land, even when they are irregular in form, but which are in easy handling distance of a market, can be profitably thinned at any time, although the profits are greater from stands in which a definite form has been secured.

There are many thousand acres of even-aged, second-growth stands in Tennessee which could be profitably thinned, even if no returns were obtained from the thinnings. Table 17 shows the composition and range of diameters of the different species in such a stand.



Fig. 8. A 20-year-old stand of yellow poplar, first quality, the larger trees being from 60 to 70 feet high and 9 to 11 inches in diameter. This stand was thinned and cleaned 5 years ago when most of the chestnut, oak and other species which were crowding the poplars were cut out. The stand now consists largely of yellow poplar and is ready for a second thinning. This should be made by removing the marked trees. It is necessary to cut some of the larger poplars whose crowns are being crowded. One such tree is marked for removal in the foreground. The heavy undergrowth of dogwood and other species which are tolerant of considerable shade is noteworthy. (Author's illustration.)

TABLE 17.—*Second-growth on coaled-over land, the stand composed of poplar and locust seedlings, chestnut sprouts, and oak seedlings and seedling-sprouts. Site as good for poplar as for chestnut. Age of stand 54 years. One acre. Carter County.*

Diameter breast-high	Poplar	Chestnut	Oak	Locust	Others
1— 3	8	12	..	..	56
6— 9	12	28	8	4	..
10—12	24	36	..	..	..
13—15	20	32	..	..	..
16—18	8	20	..	4	..
	72	128	8	8	56
Total per acre above 9 inches.	54	88	..	4	..

The poplars above 12 inches in diameter are 115 feet high; the chestnut of the same sizes are from 108 to 110 feet high. Such a site is well suited for the production of large sized poplar timber, and the crowns of the poplars, which are still being crowded by the chestnut, should be freed by cutting the latter. This would be a combined thinning and elimination cutting. Had some of the chestnut been removed in successive earlier thinnings, it would have been possible to have forced all of the poplar to diameters above 14 inches. The chestnuts can now be removed for poles, the most profitable form in which they can be marketed, and the locust should be cut, but the poplar should be held until the accelerated growth which followed the thinning begins to decline. (See Figs. 1 and 3.)

BETTER UTILIZATION.

Reduction of waste.—Since the most valuable timber in the trees is in the butt log, stumps of sound trees should be cut just as low as possible. In the case of crooked trees, log lengths should be varied so that there will be no crooked logs or so that the crooks will be near the end of the logs. Sound timber in the top should be used whenever the selling price of the lumber in it, less the discount, exceeds the value of the labor in converting it. This secures the removal of tops which may be a fire menace, without materially reducing profits or stumpage value. As soon, however, as the value of the lumber in a log is less than the cost of the labor to convert it, its removal results in a reduction in the value of the remaining logs of a tree. Consequently, very limby and knotty top logs which will yield not to exceed 25 per cent. of No. 2 Common or better, and the lumber from which would have a net value of \$10 per 1,000 feet, after deducting overhead charges, stumpage and trade discounts, should

not be removed when labor items, including delivery on cars, amount to more than this.

Where trees are short bodied and low grade, but sound, a large portion of the timber being of unprofitable character, the tree should be held, since some growth is taking place and this, added to the appreciation in the price of stumpage which is rapid in the case of low grade timber (see Table No. 12), will eventually assure the removal of such trees at a profit.

Selling timber in the most profitable form.—The wood of second growth yellow poplar is commonly measured either as logs scaled by Doyle-Scribner rule, or as cords of 128 cubic feet of piled wood with the bark on, or as cords of 160 cubic feet of piled wood with the bark peeled. It is frequently desirable to determine before cutting the most profitable form in which to market small trees. Veneer is generally cut from logs 16 inches and over in diameter, and is measured by the cubic feet of solid wood in the log. There is consequently no difficulty in ascertaining the relative value of logs marketed for veneer stock, and measured by a log scale.

The relative value of small trees of different sizes for pulp cordwood and for saw timber is shown in Table 18. Stumpage values in the table are placed at \$1 per 1,000 feet for lumber, measured by Doyle-Scribner rule; and at \$1 a cord of 160 cubic feet for wood measured after it is rossed, dried, and racked. To use this table it is necessary to multiply the volumes which are given in the table for trees of each diameter, by the relation of the stumpage at \$1 to the actual stumpage price which is offered, using as a basal diameter the diameter breast-high of the average sized tree on the tract. For example: if board measure stumpage were worth \$1.50 per 1,000 feet, the volume which is given for the average tree in the board-measure column should be multiplied by 1.50. If the cordwood stumpage measured after peeling were worth 50 cents a cord, the value given of the average sized tree which is under this head should be multiplied by .50. A comparison of the two resultant figures will show in which form the timber could be marketed most profitably.

Table 19 shows the number of trees required to make a cord of 160 cubic feet after they are peeled, split, and dried.

TABLE 18.—*Comparative value of trees of yellow poplar of different sizes for cordwood, peeled, and for lumber (scaled by Doyle-Scribner rule).*

(Based on the average tree.)

Diameter breast-high Inches	Cordwood, 160 cubic feet, measured after peeling, at \$1.00 per cord	Saw logs scaled by Doyle-Scribner rule, at \$1.00 per 1,000 board feet
6		
7	.04	
8	.066	.01
9	.086	.014
10	.11	.024
11	.13	.031
12	.163	.05
13	.20	.075
14	.25	.10
15	.32	.13
16	.40	.163
17	.48	.20
18	.52	.243

TABLE 19.—*Number of trees of yellow poplar split and peeled in second-growth stands 25 to 50 years old required to make a long cord of 160 cubic feet; the percentage of bark, and the percentage of waste in stump, top, and bark.*

Diameter breast- high Inches	Number of trees (stem wood only to 3 inches) to a long cord split and peeled	Double thickness of bark at breast- high Inches	Percentage of bark in the stem	Height of stump feet	Percentage of wood lost in stump, bark and top of stem (top used to 3 inches)
7	23.	.9	20	1.3	27
8	15.2	1.0	19	1.3	25
9	12.0	1.5	18	1.4	24
10	9.4	1.1	18	1.4	23
11	7.6	1.2	17	1.4	22
12	6.1	1.3	17	1.4	22
13	5.0	1.4	17	1.5	21
14	4.0	1.4	17	1.5	21
15	3.1	1.4	16	1.6	21
16	2.5	1.5	16	1.7	21
17	2.1	1.5	16	1.7	21
18	1.9	1.5	16	1.8	21
19	1.7	1.5	15	1.9	20
20	1.5	1.6	15	2.	20

PLANTATIONS.

Yellow poplar can be easily and cheaply grown from plants raised in a nursery or taken from the forest or edges of fields and pastures. Seeds cost from 40 cents to \$1.00 a pound. There are about 9,000 seeds to a pound. Their vitality, however, is low, it being the exception when more than 15 per cent. of the seed are sound. The seed can be planted either in the fall or in the spring. If planting, however, is to be deferred until spring, the seed should be stratified in moist sand immediately after collection in the fall, and kept in this manner until they are to be planted in the spring. If they are permitted to dry out and then planted the succeeding spring, not only do most of them lie over in the soil a year before germinating, but there is a decline in germinability. Seed should be sown in broad shallow rows 18 inches apart and covered not more than one-half inch. Unless the seed bed is established in the forest, and receives some shade from the surrounding trees, the seedlings should be given a light shade with a screen of laths or brush during the first summer. If the soil of the seed bed is fertile, the seedlings when a year old should be at least one foot high. They will have long tap-roots which must be cut off when out-planted. It is not desirable to transplant in the nursery. While one-year-old plants will usually be used for permanent planting it is possible to outplant the seedling when from three weeks to two months old. The taproot at this age is small and need not be cut. On fertile sites spacing in permanent planting should be six by six feet; on poor sites five by five feet.

Plantations can be made on any sites which have a deep, porous soil, well provided with humus, and neither wet nor extremely dry. Heaviest yields can be expected from sites on which large trees of yellow poplar occurred in the original forest. It is possible, however, to grow poplar in plantations on far drier sites than are naturally occupied by the trees, but it is desirable in planting on such dry sites to mix the poplar with some species like white pine, red oak, white oak, or chestnut, which have a more dense canopy than poplar and will better protect the soil than this species. On moist sites, poplar can be mixed with hard maple, white pine, or basswood. At high elevations in the Cumberland Mountains and in the mountains between North Carolina and Tennessee, poplar can be mixed with white ash or black cherry. Such mixture, however, should be made only on fertile soils, preferably on north slopes. Where there is a good market for locust posts and the locust is not seriously attacked by the borer, this species can be mixed with yellow poplar. The locust can be removed for posts in thinnings, leaving the poplar for the permanent tree.

It is necessary to thin plantations of yellow poplar as the trees become large and crowding takes place. This requirement should be considered

in making mixtures and at least a portion of the trees in such mixtures should be species, the wood of which can be profitably used when of small size. In establishing mixed plantations, the different species can be planted in separate rows, or each species can be planted so as to occupy a small group. The cost of planting is cheaper when the species are separated in rows, but the thinnings are easier executed when the species are separated in groups. The groups can be from one-half to one rod square.

It is not necessary that the land should be plowed, but it is necessary that it should be open, and that there should be no growth which will smother or choke the young plants. Plantations should never be established on very grassy sites or beneath thickets or shrubs. In planting cut-over land, this must be kept in mind, and plantations should be only on sites which are open. The growth of the seedling, however, is far more rapid on good sites than on poor sites, and while it will soon overtop brambles and such low shrubs in the rich soil of coves, it is likely to be smothered by them in less favorable localities. Table No. 20 shows the most profitable age for cutting yellow poplar in thinned planted stands, and the cost per 1,000 board feet of growing the timber. The profit shown is the net profit above all interest on the investment, which is calculated at 5 per cent. a year, compounded. There is an additional profit, which is not shown, in the increase in the value of stumpage. If this should be at the rate of 3 per cent. per annum, which is one-fourth of the rate of increase in price during the past 20 years, the investment would earn more than 10 per cent a year, compounded, when the stand is 40 years or more old.

COST OF GROWING YELLOW POPLAR IN PLANTATIONS.

Table 21 shows the cost of growing yellow poplar in unthinned plantations on different sites, and the rate per cent. which would be yielded on the initial investment indicated in the table.

TABLE 21.—Cost per 1,000 board feet of growing yellow poplar in plantations. Interest rate 5 per cent; cost of stocking \$6 an acre.

Age of stand	Value of stand at present prices	Average annual increase in value per acre	Total* expenses in growing timber per acre	Profit or loss in excess of 5 per cent. per acre	Cost of growing stand Per 1,000 feet	Rate of in-		Rate of in-	
						crease in stumpage at present prices	crease in age values necessary to yield 5 per cent. net	crease in value of stand per acre	Per cent.
Years						Per acre	Per cent.	Per cent.	
20	\$4.18	\$2.30	\$ 37.41	\$ 8.59	\$ 3.40	\$ 46	..	20.0	
30	4.80	3.13	73.80	20.20	3.77	94	..	7.4	
40	5.34	3.58	137.39	5.61	5.13	143	..	4.2	
50	5.44	3.60	244.88	64.88	7.40	180	.6	2.3	
60	5.29	3.38	423.00	220.00	11.02	203	1.2	1.6	
Average conditions II—Value of soil \$5 an acre									
20	\$3.33	\$0.85	\$ 27.49	\$ 10.49	\$ 5.39	\$ 17	2.2	23.0	
30	3.33	1.43	51.01	8.01	3.95	43	.6	9.4	
40	4.02	1.95	91.72	13.72	4.73	78	.4	6.0	
50	4.52	2.28	161.39	47.39	6.40	114	.7	3.8	
60	4.72	2.38	277.17	134.17	9.15	143	1.1	2.3	
Poor conditions III—Value of soil \$3 an acre									
20	\$3.57	\$0.25	\$ 23.52	\$ 18.52	\$16.80	\$ 5	8.4	23.0	
30	3.16	.83	41.82	16.82	5.29	25	1.7	16.0	
40	3.72	1.28	73.81	22.81	5.39	.51	.9	7.2	
50	4.30	1.60	128.00	48.00	6.88	80	.9	4.6	
60	4.59	1.75	218.82	113.82	9.56	105	1.2	2.7	

*See Table— for detailed statement of elements expense.

Soil value.—The cost of growing yellow poplar in plantations as shown in Table 21 is based on a soil value of \$10 an acre for best quality sites, of \$5 an acre for average quality sites, and \$3 an acre for poor quality sites. These are reasonable values for sites which are in a suitable condition for planting. If the land is situated in a farming section the values of soils which produce yellow poplar, even if the sites are extremely rough, will not be less than these. If it is situated in a cut-over mountainous section where the average value of the soil does not exceed \$2 an acre, the sites suited for yellow poplar would embrace only the very best soils—the coves and lower slopes—which would amount probably to less than 20 per cent. of the area of any large tract. One-third of this 20 per cent. might have a growing capacity equal to that given for the best quality sites, while that of the remaining two-thirds would be less. Its relative value consequently would be far greater than that of the other 80 per cent. of the tract. If the land were foul, making it necessary to cut off some of the brush, as would often be the case, this would add to the cost of planting and counterbalance its apparent cheapness.

Cost of planting.—The cost of planting one-year-old seedlings, including the cost of the planting stock as well as the labor, is placed at \$6.00 an acre, a low figure, but possible if the work is economically done and if the seedlings are home grown. On the best sites where spacing need be only 8x8 feet (680 trees to the acre) the cost would be less. On poor sites where a spacing of 6x6 feet should be used (1,200 trees to the acre) the cost of planting yearlings should not exceed \$6.00.

Yield.—Yield of plantations is calculated on the basis only of thinning stands (page —) since it is doubtful if any plantations will be established except where thinning can be made. The material from thinning is given a value of \$2.00 a cord, a high value for the small-sized wood from the early thinning but low for the larger-sized wood from the older stands. Interest is allowed on the value of thinnings of four per cent. net, accrued for each five years.

Interest rate.—A five per cent. rate is allowed on all expenses connected with establishing the plantation and taxes, except in the returns from thinnings, on which only four per cent. is allowed.

Protection.—For the cost of protection and superintendence, five cents an acre a year is allowed. In the case of estates and farmer's plantations this cost can be entirely eliminated. In the case of forest plantations the cost of protection may exceed this item for the first 20 years. It should rapidly decrease, however, with the age of the stand and with succeeding thinnings.

Taxes.—A uniform tax of 1.20 per cent. on the actual soil value (\$5 an acre) is allowed for the entire period. The tax on the timber is assumed not to begin until the stand is 20 years old, at which period the stand begins to acquire merchantable value. The actual value at the end of each five years is taken as the assessed value, with a tax rate of one per cent.

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